CHAPTER 14

RESISTANCE MEASUREMENT (PART 1)

Voltmeters and ammeters inserted in a circuit have been assumed to have no effect on the overall resistance, current and voltage drops within that circuit. In many cases, the effect on the circuit parameters, when a meter is connected in the circuit, is so small that it may be neglected. In certain instances, however, care must be taken when selecting the position where the meter is to be inserted into a circuit. Incorrect positioning of a meter may result in errors of more than one hundred percent when Ohm's Law is applied to the meter readings.

14.1 POSSIBLE METER CONNECTIONS

The standard procedure so far in this course has been in connect an ammeter in series with the resistance to be measured and to connect a voltmeter across the supply. (Figure 14.1).

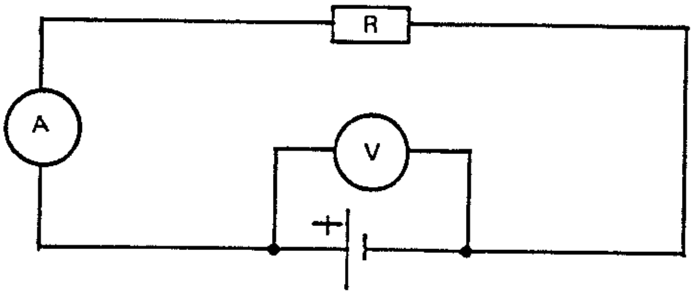


Figure 14.1

Then by Ohm's Law

$$R = \frac{E}{I} \text{ ohms}$$

In chapter 3 it was explained that a voltmeter has a high resistance, usually in the range of thousands of ohms, while the ammeter has a low resistance this being less than one ohm. A simple method of illustrating the internal resistance of a meter is to draw the internal resistance outside the meter and assume the meter itself has zero resistance. (Figure 14.2).

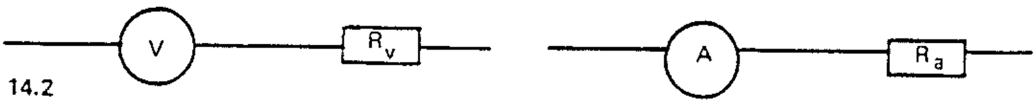


Figure 14.2

While the ammeter must be connected in series with the resistance under test, the voltmeter may be connected across both the resistance and the ammeter, or across the resistance only. (Figure 14.3).

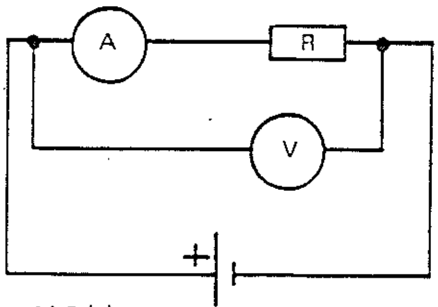


Figure 14.3 (a)

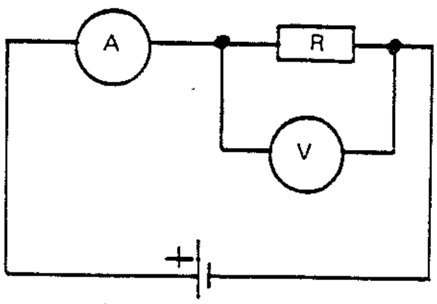


Figure 14.3 (b)

Figure 14.3 is redrawn in Figure 14.4 with the internal resistances of the meters included in the circuits.

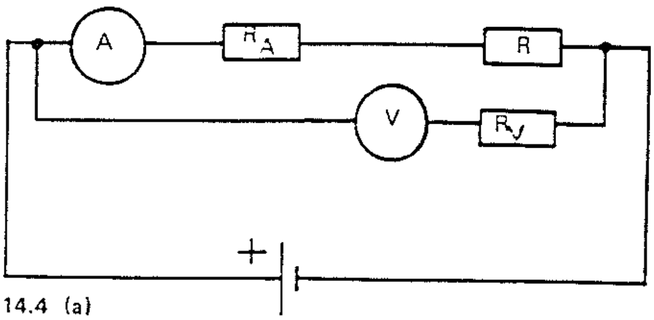


Figure 14.4 (a)

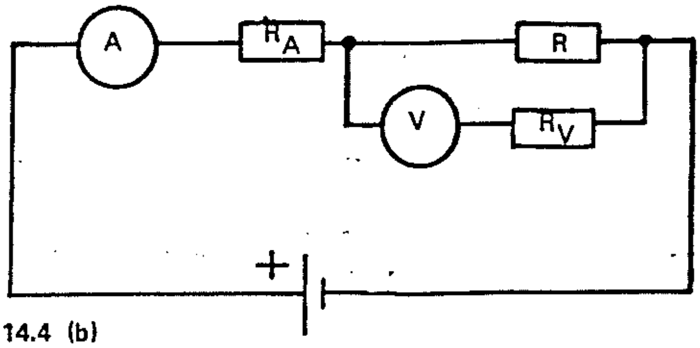


Figure 14.4 (b)

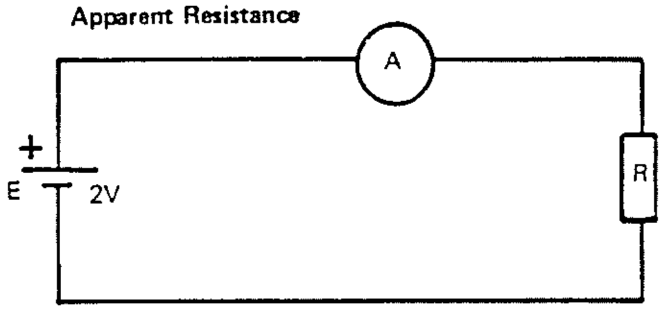
Referring back to Chapter 11, it can be seen that there are two completely different series-parallel circuits. If E, R_A and R_V are the same for each circuit, then the total resistance of the circuit and the current drawn from the source, must depend on the value of the resistance under test. The method of connection used in Figure 14.3 (a) is known as the long shunt connection, while the method used in 14.3 (b) is called the short shunt connection. Errors that can occur, due to incorrect positioning of meters, are illustrated in the following problems.

14.2 LOW VALUES OF RESISTANCE

Example 14.1

An ammeter connected in series to an resistor of unknown value reads 10 amperes when connected to a 2 volt d.c. source. The resistance of the ammeter is 0.1 ohms. Using a voltmeter whose resistance is 2000 ohms, determine which volt-ammeter method is more suited for calculating the value of the unknown resistor.

Apparent Resistance



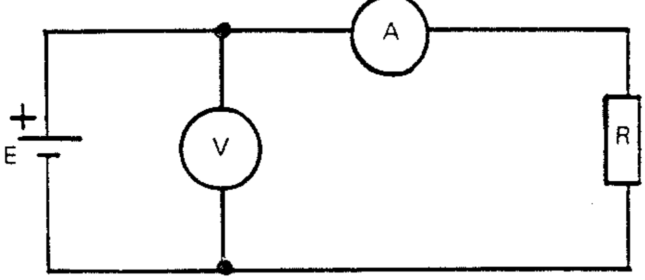
Let R be the value of the unknown resistor, then -

$$R = \frac{E}{I}$$

$$= \frac{2}{10}$$

$$= 0.2\ \Omega$$

(a) Long Shunt Method

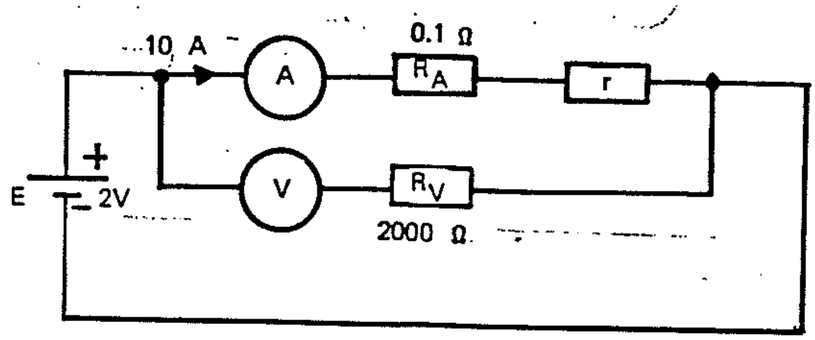


$$\text{Apparent Resistance} = \frac{E}{I}$$

$$= \frac{2}{10}$$

$$= 0.2\ \Omega$$

Including the internal resistances of the meters gives the following circuit.



The 10 ampere current flows through the ammeter resistance and the unknown resistor. The voltage drop across the ammeter is given by -

$$IR_A = 10 \times 0.1$$
$$= 1 \text{ V}$$

Therefore the voltage drop across the resistor under test must be —

$$V_R = E - I R_A$$
$$= 2 - 1$$
$$= 1 \text{ V}$$

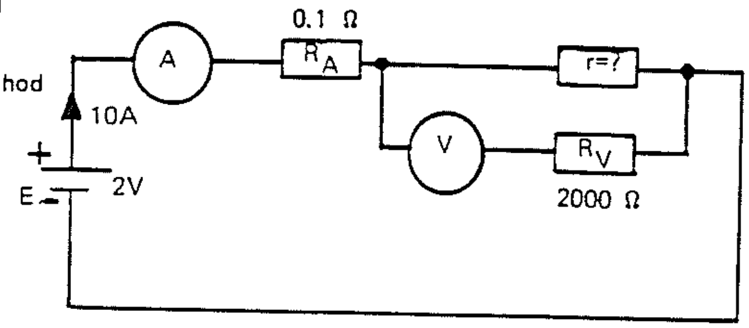
The true value of the unknown resistor will be -

$$r = \frac{V_R}{I}$$
$$= \frac{1}{10}$$
$$= 0.1 \text{ ohm}$$

Clearly then, if the long shunt method is used to measure the value of this resistor the error is -

$$\frac{1}{1} \times \frac{100}{1} = 100\% \text{ error}$$

(b) Short Shunt Method



The 10 A current flows through R_A then divides into current through the voltmeter and through the unknown resistor.

Voltage drop across R_A $= I R_A$

$$= 10 \times 0.1$$
$$= 1 \text{ V}$$

Therefore voltage drop across r $= E - I R_A$

$$= 2 - 1$$
$$= 1 \text{ V}.$$

Current through voltmeter $= \dfrac{E - I R_A}{R_V}$

$= \dfrac{1}{2000}$

$= 0.0005$ A.

Therefore current in r $= I - I_r$

$= 10 - 0.0005$

$= 9.9995$A

Resistance of r $= \dfrac{V_r}{I_r}$

$= \dfrac{1}{9.9995}$

$= 0.100005$

The error produced by using this method is —

$$\frac{0.100005 - 0.1}{0.1} \times 100 = \frac{0.00005}{0.1} \times 100$$

$= 0.05\%$ error

14.3 HIGH VALUES OF RESISTANCE

Example 14.2

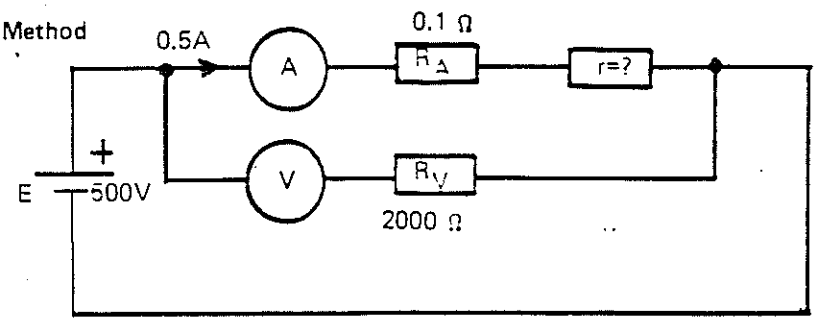
An ammeter connected in series to a resistor of unknown value reads 0.5 amperes when connected to a 500 V d.c. supply. The resistance of the ammeter is 0.1 ohms. Using a voltmeter whose resistance is 2000 ohms, determine which volt-ammeter method is best suited to calculate the value of the unknown resistor.

Apparent resistance $= \dfrac{E}{I}$

$= \dfrac{500}{0.5}$

$= 1000\ \Omega$

(a) Long Shunt Method



Voltage drop across the ammeter

$I R_A = 0.5 \times 0.1$

$= 0.05$ V

Voltage drop across the unknown resistor

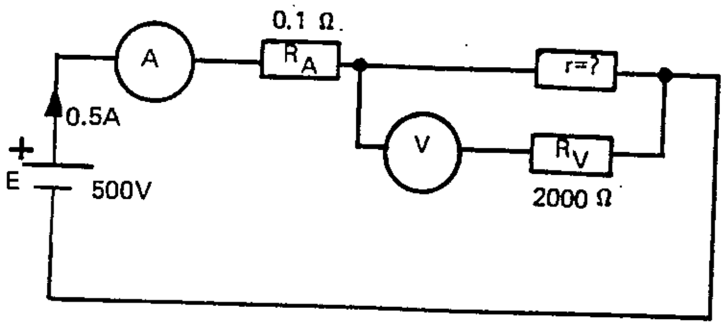
$$I_r = E - I R_A$$
$$= 500 - 0.05$$
$$= 499.95 \text{ V}$$

$$r = \frac{E - I.R_A}{\text{[illegible]}}$$
$$= \frac{499.95}{0.5}$$
$$= 999 \text{ ohm}$$

Error by this method

$$\frac{1000 - 999}{999} \times 100 = \frac{1 \times 100}{999} = 0.1\% \text{ error}$$
$$= 0.1\% \text{ error}$$

(b) Short Shunt Method



Voltage drop across R_A $= I R_A$
$$= 0.5 \times 0.1$$
$$= 0.05 \text{ V}$$

Voltage drop across r $= E - IR_A$
$$= 500 - 0.05$$
$$= 499.95 \text{ V}$$

Current through voltmeter $= \frac{E - I R_A}{R_v}$
$$= \frac{499.95}{2000}$$
$$= 0.2497 \text{ A}$$

$$\text{Current in } r = I - I_v$$

$$= 0.5 - 2.497$$

$$= 0.2503 \text{ A}$$

$$\text{Resistance of } r = \frac{V_r}{I_r}$$

$$= \frac{499.95}{0.2503}$$

$$= 1997.4\ \Omega$$

Error by this method

$$\frac{1995.6 - 999}{999} \times 100 = \frac{996.6}{999} \times 100$$

$$= 99.76 \quad \text{error}$$

CONCLUSIONS

From the two examples it can be seen that large errors can be made using either method, the error depending on the value of the resistor to be measured.

In general –

(a) If the resistance to be measured is low, the short shunt method should be used.

(b) If the resistance to be measured is high, the long shunt method should be used.

TUTORIALS 1.14

(1) The short and long shunt method of measuring resistance are used to measure an unknown resistor. The voltmeter and the ammeter have resistances of 1,500 ohms and 0.08 ohms respectively. The supply voltages is 120 volts and the ammeter indicates 0.125 amperes in each test. Determine the best method to apply to the resistor and the percent error in each case.

(2) A resistor has a known resistance of 500 ohms. A voltmeter (resistance 1000 ohms) and an ammeter (resistance 0.2 ohms) are used in conjunction with a 300 volt supply in a short and long shunt test on the resistor. Calculate the percent error in each case.

(3) The voltammeter method of measuring resistance is used to measure the resistance of a 1 ohm resistor. The voltmeter has a resistance of 1000 ohms and the ammeter has a resistance of 0.2 ohms. If the voltmeter indicates 5 volts in both long and short shunt calculate the error involved in both methods.